

## Cardiac MRI: 3.0T

Paul Finn, MD

David Geffen School of Medicine at UCLA



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## Acknowledgements

- Stefan Ruehm, MD
- Kambiz Nael, MD
- Roya Saleh, MD
- Anthony Ton, MD
- Mayil Krishnam, MD
- Sergio Godines, RT
- Glen Nyborg, RT
- Howard Dinh, MD
- Carissa Fonseca, Ph
- Gerhard Laub, PhD
- Vibhas Deshpande, PhD
- Hanns Weinmann, PhD

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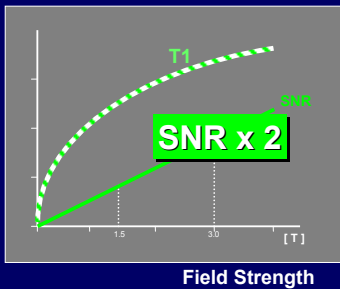
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## 3 Tesla: Advantages



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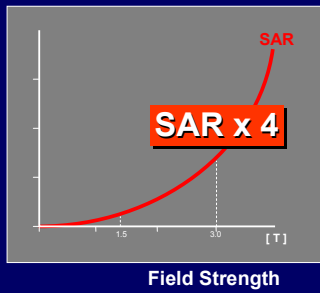
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### 3 Tesla: Disadvantages



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### Cardiac MRI at 3.0T

- Why?
- Needs to compete favorably with cardiac MRI at 1.5T

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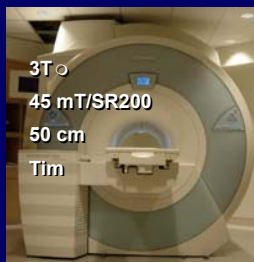
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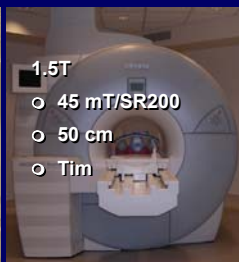
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### Tim Trio



### Tim Avanto



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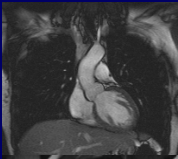
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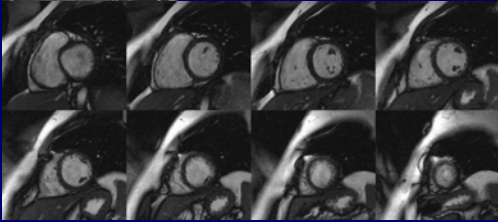
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**Cardiac Cine MRI at 1.5T**  
**\*Breath-hold Segmented SSFP Cine**



\* Carr JC, et al. Radiology  
2001;219:828-834.



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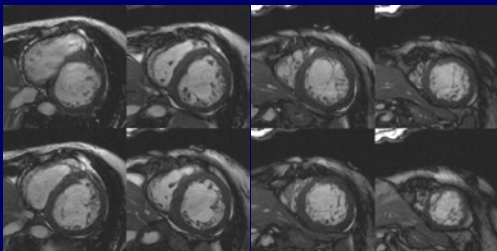
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**Segmented TrueFISP Cine: 1.5T**



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**General Trends at 3.0T vs 1.5T**

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## Increased SAR

- Limits flip angles and minimum TR for high-performance sequences
  - SSFP cine
  - Spin echo train imaging
  - CEMRA

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## Increased SNR

- Potential benefits for techniques which have borderline SNR
  - Perfusion imaging
  - Viability imaging with delayed enhancement
  - Coronary imaging

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## B1 Inhomogeneity

- Shading in some regions
- Inhomogeneous contrast in some regions
- May make calibration of RF transmitter voltages difficult – varying flip angles within body regions

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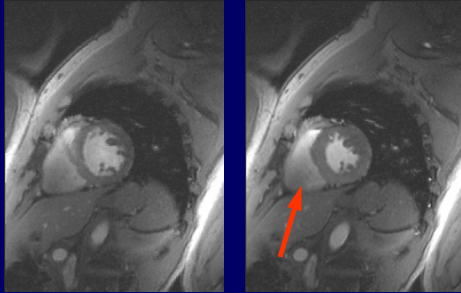
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### B1-Inhomogeneity



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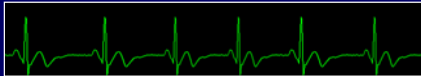
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### Magneto-hydrodynamic effect

- Increased sensitivity to flow-induced noise on ECG trace can make gating more problematic



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### Cine MRI at 3.0T vs 1.5T

- SSFP now the standard at 1.5T
  - TrueFISP
  - FIESTA
  - Balanced FFE
- At 3.0T, SSFP cine is challenging

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### Cine MRI at 3.0T vs 1.5T

- Ideal conditions for TrueFISP cine
  - TR as short as possible
  - Flip angle high and uniform
  - Very homogeneous magnetic field
- At 3.0T, all of these conditions are violated due to a combination of SAR, patient-induced susceptibility gradients and dielectric resonance effects

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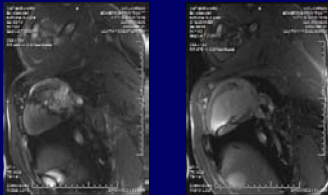
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### 3T Functional Cardiac Imaging SSFP cine: off-resonance artifact



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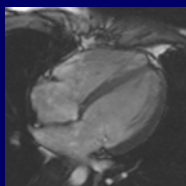
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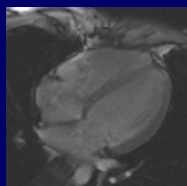
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### SAR-Limitations: Effects on TrueFISP cine



$\alpha = 50$  deg



$\alpha = 30$  deg

→ lower CNR

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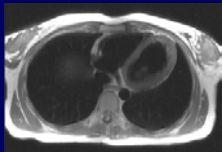
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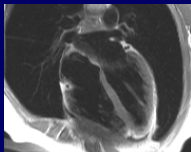
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## Dark-blood Imaging @ 3T: long „TR“



db-HASTE



db - TSE

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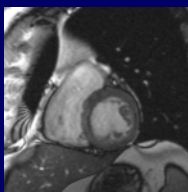
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## Cardiac Function @ 3T



TrueFISP, 40°



FLASH, 20°

- Use longer RF pulses than at 1.5T
- flip angle around 30° - 40° (less signal and contrast)

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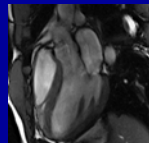
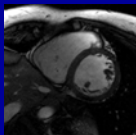
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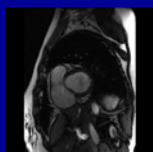
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## Cardiac TrueFISP imaging at 3T



with PAT x2  
TA 8 sec



8-channel cardiac array coil

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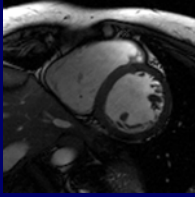
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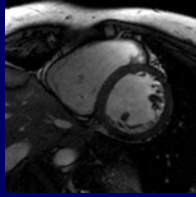
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## Parallel Imaging @ 3T



without iPAT

15 sec



with iPAT x2

8 sec

Temporal resolution 25 msec  
Matrix: 256x256

TrueFISP short axis

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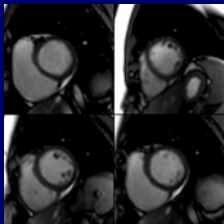
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## Cardiac Function @ 3T



Cine TrueFISP  
iPAT x2  
4 slices in 12 sec  
3.5 x 2.8 x 8 mm  
Temporal resolution = 25 ms

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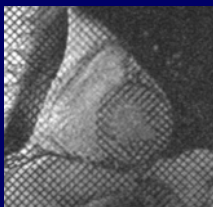
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## Tagging



Longer T1 @ 3T keeps tags visible longer

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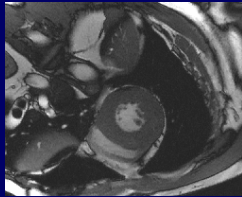
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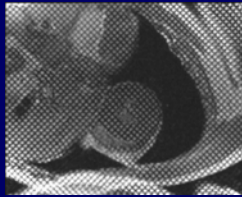
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## Functional MRI @ 3T (LVH)



TrueFISP cine



grid tagging

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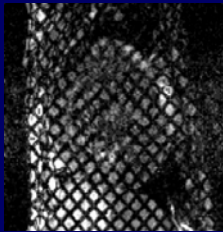
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## But: With TrueFISP Cardiac Tagging at 1.5T

Better persistence of  
tags than with SGRE



1.0mm x 1.5mm x 6 mm voxels  
30 msec temporal resolution  
7 second acquisition

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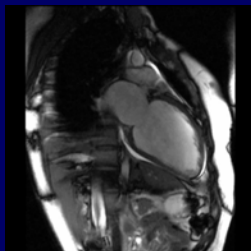
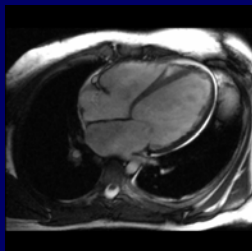
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## Cardiac Function @ 3T



Cine TrueFISP

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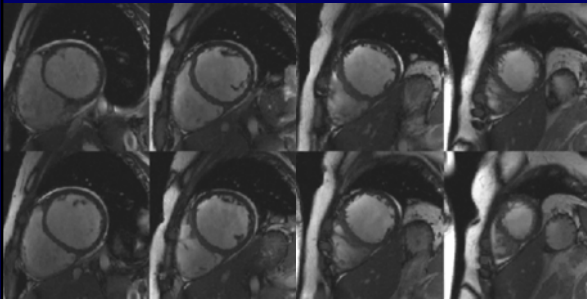
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courtesy of Dr. Miller, University of Tuebingen

## Cardiac Function @ 3T



Cine TrueFISP

courtesy of Dr. Miller, University of Tuebingen

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## Current status of Cine MRI at 3.0T vs 1.5T

- SSFP cine at 3.0T is more sensitive to off-resonance effects than at 1.5T
- Can be 'managed' by attention to shim status and by adjusting frequency offsets on a slice-orientation basis
- In an individual case, may work; or may not

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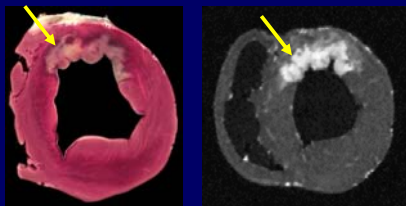
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## Contrast Enhancement in Infarction



TTC

MRI

Ex-vivo comparison of TTC and Gd-enhanced MRI in infarcted myocardium

courtesy of Dr. R. Judd, Northwestern University, Chicago

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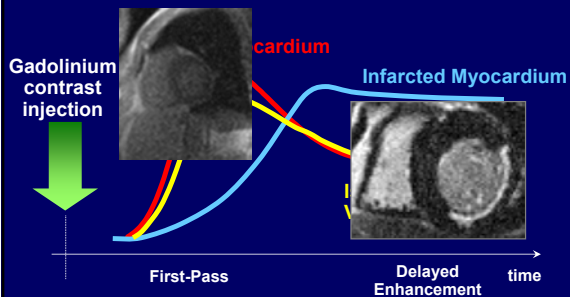
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## Evaluation of Viability and Myocardial Perfusion with IV contrast

Note: Gd is not FDA approved for cardiac imaging




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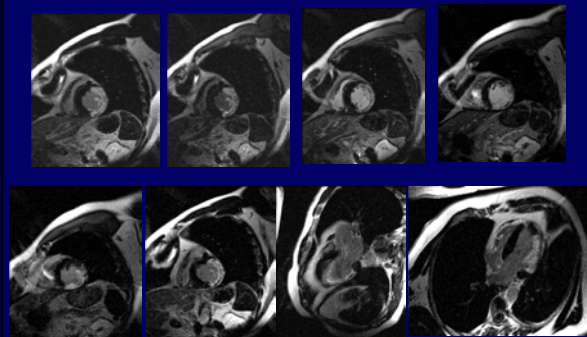
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## Left Circumflex distribution infarction: 1.5T




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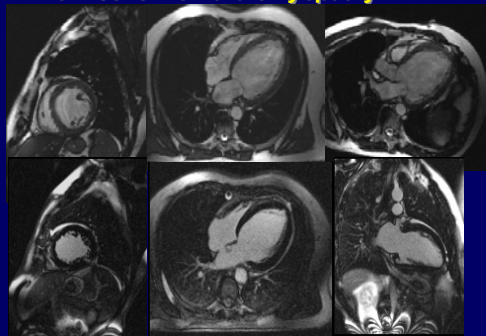
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## Segmented TrueFISP: Cine and Viability @ 1.5T Non-Ischemic Cardiomyopathy



IR TrueFISP: 64 lines / heart beat

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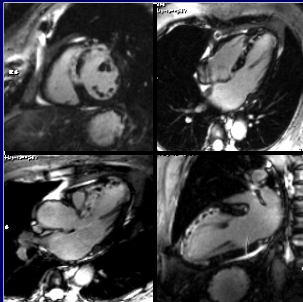
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## Viability @ 3T



IR single shot TrueFISP

Courtesy of Dr. Regenfuss, University of Erlangen

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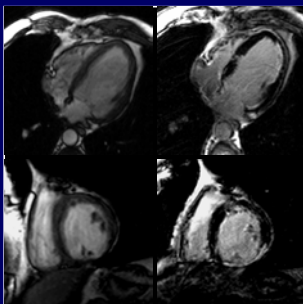
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## Viability & Function @ 3T



Cine TrueFISP

IR single shot  
TrueFISP

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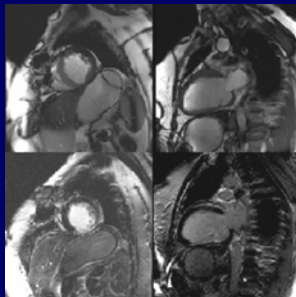
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## Viability & Function @ 3T



Cine TrueFISP

IR TurboFLASH

courtesy of Dr. Miller, University of Tuebingen

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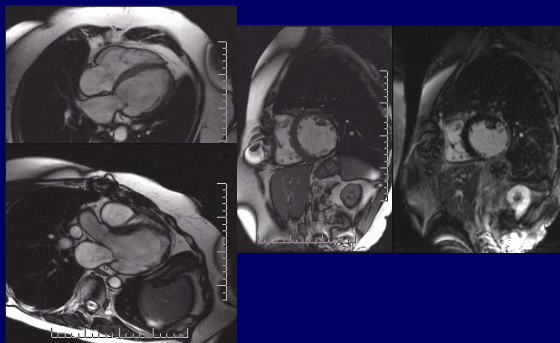
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### Lt Cx Infarction: 1.5T



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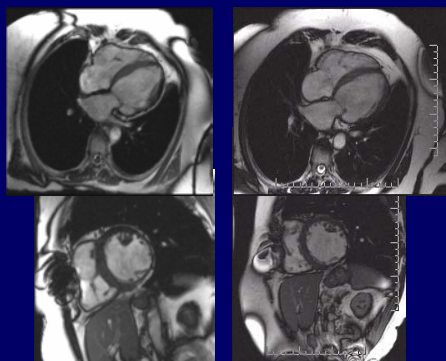
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### Lt Cx Infarction cine: 3.0T vs 1.5T



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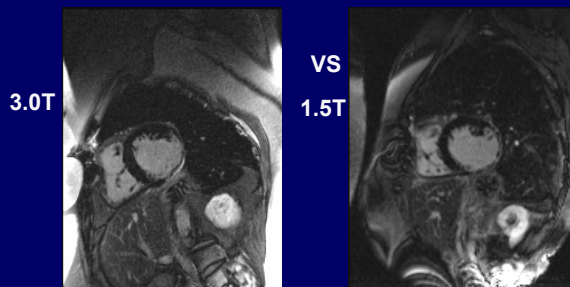
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### Lt Cx Infarction: Viability



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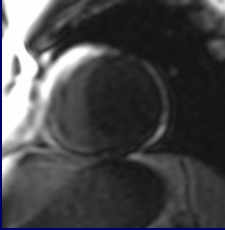
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## Perfusion @ 3T



SR single shot  
Turboflash  
First pass  
iPAT x2  
4 slices/heartbeat

Courtesy of Dr Regenfuss, University of Erlangen

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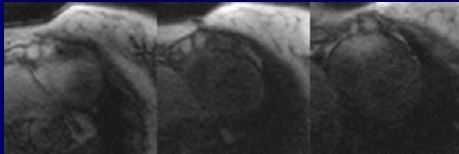
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## First-Pass Imaging at 3.0T TurboFLASH + iPAT



Optimized Saturation Recovery Pulse for  
Reduced B1 Sensitivity

Northwestern University, Chicago

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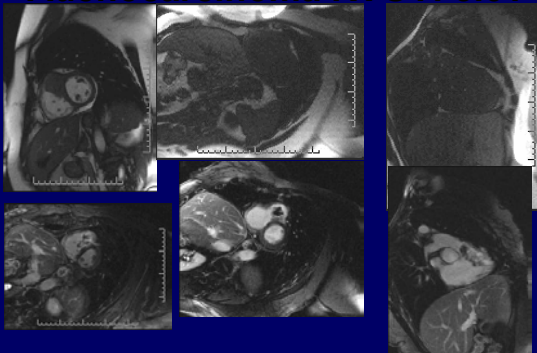
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## Adenocarcinoma RVOT: 3.0T



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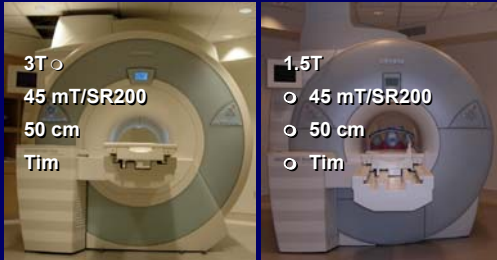
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**32 channel Tim Trio: 32 channel Tim Avanto**



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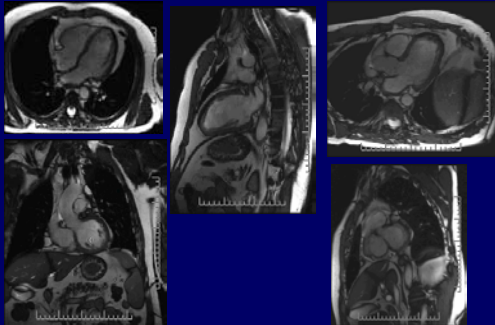
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**Cardiac MRI at 3.0T: Pre-RF Ablation**

SSFP CINE



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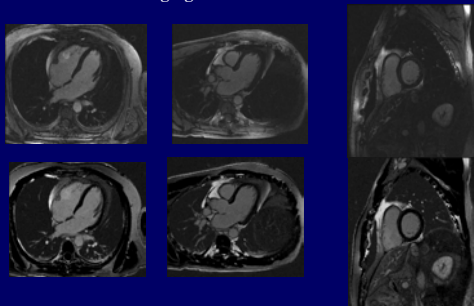
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**Cardiac MRI at 3.0T: Pre-RF Ablation**

Delayed Contrast enhancement Viability Imaging



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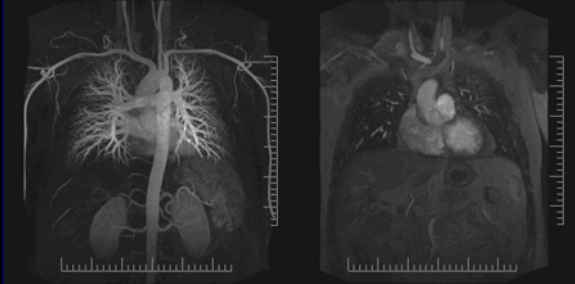
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### Cardiac MRI at 3.0T: Pre-RF Ablation

#### Pulmonary Vein Anatomy



500 mm FOV 576 matrix

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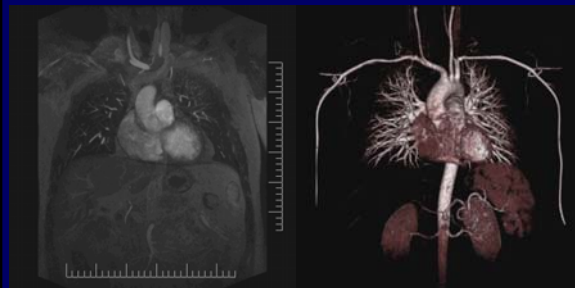
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### Cardiac MRI at 3.0T: Pre-RF Ablation

#### Pulmonary Vein Anatomy



500 mm FOV 576 matrix

Volume rendering

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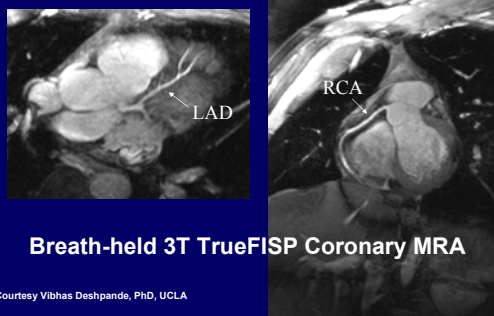
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### Coronary MRA @ 3T



Breath-held 3T TrueFISP Coronary MRA

Courtesy Vibhas Deshpande, PhD, UCLA

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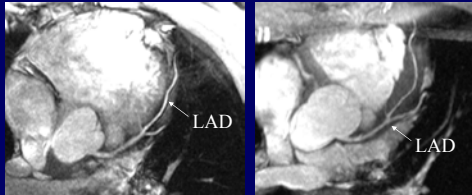
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## Coronary MRA @ 3T



3T TrueFISP Coronary MR Angiography  
(breath-hold, 28 heart beats)

UCLA

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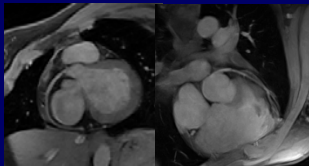
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## Coronary MRA @ 3T



8-channel cardiac array  
Active electrode ECG triggering  
1D PACE for motion correction

TA: 6:27 min  
Pixelsize: 0.9 x 0.9 x 1.2 mm

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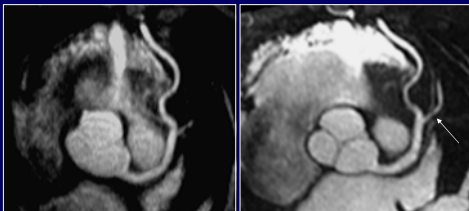
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## Coronary MRA *Contrast-enhanced FLASH*



1.5T

3.0T

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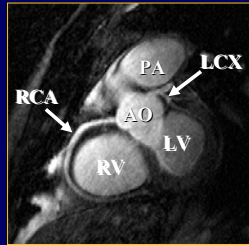
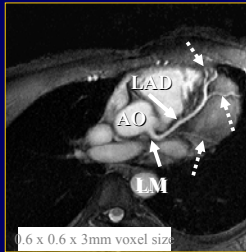
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Courtesy of Drs X Bi, D Li, Northwestern University, Chicago.  
X. Bi, D. Li, Northwestern University

## 3T Coronary MRA: Results

Courtesy Matthias Stuber, PhD, Johns Hopkins University

3T Coronary MRA in-vivo & in humans



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## But: Coronary CT Angiography!



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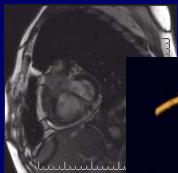
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## Right Heart Failure



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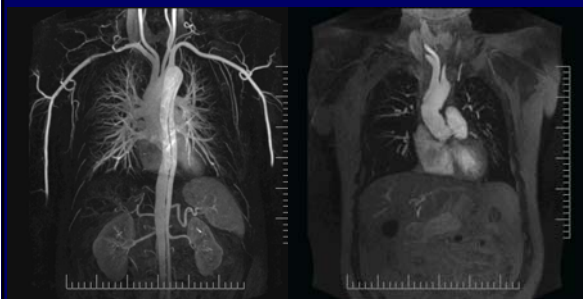
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### TIM Trio: Thorax - dissection



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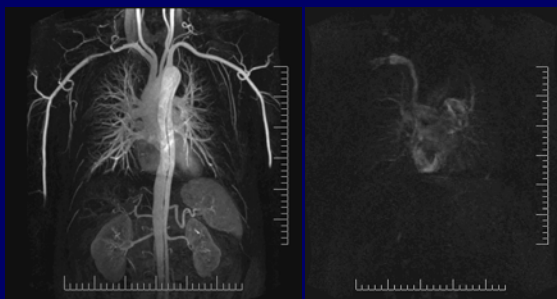
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### TIM Trio: Thorax - dissection



6ml Gd, 12 measurements each 1.7 s apart  
21 s breath hold: iPAT x 3

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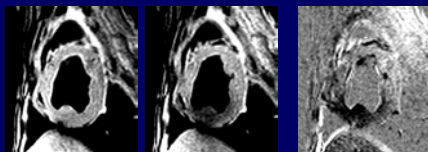
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### Myocardial BOLD Imaging at 3T

Rest (R)      Stress +  
                         Stenosis (SS)      SS - R



Dog with LCx stenosis

Shea, D Li. Northwestern University, Chicago, Illinois.

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## Summary

- Promising results for cardiac MR @ 3T.
- Limitations for SSFP cine
- The increased SNR is advantageous for viability imaging, dynamic angiography and perfusion imaging.
- Areas to be addressed
  - protocols and sequence design with reduced SAR, reduced B1 sensitivity
  - Contrast agents?

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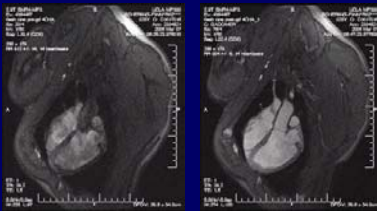
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## 3T Functional Cardiac Imaging



Gadomer, pig study. Schering AG, Inc.

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## 3T Functional Cardiac Imaging



Gadomer, pig study. Schering AG, Inc.

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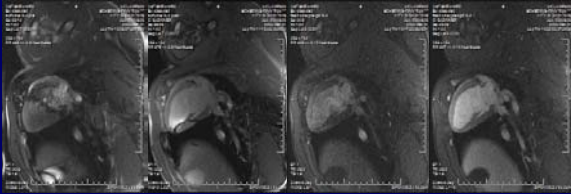
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## 3T Functional Cardiac Imaging



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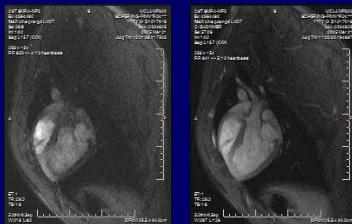
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## 3T Functional Cardiac Imaging



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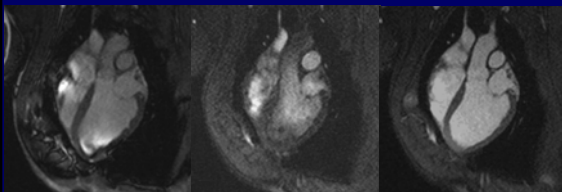
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## 3T Functional Cardiac Imaging



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**Thank you**



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